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Vorem Harsha Kiran

M.Sc. Scholar, Division of
Agronomy, School of Agricultural
Sciences, Karunya Institute of
Technology and Sciences,
Coimbatore, Tamil Nadu, India

Dr. Augustine R

Associate Professor, Division of
Agronomy, School of Agricultural
Sciences, Karunya Institute of
Technology and Sciences,
Coimbatore, Tamil Nadu, India

Dr. Praveena Katharine

Assistant Professor, Division of
Soil Science, School of Agricultural
Sciences, Karunya Institute of
Technology and Sciences,
Coimbatore, Tamil Nadu, India

Dr. Lydia Pramitha

Assistant Professor, Division of
Genetics and Plant Breeding,
School of Agricultural Sciences,
Karunya Institute of Technology
and Sciences, Coimbatore, Tamil
Nadu, India

Dr. Nivethitha M

Assistant Professor, Division of
Genetics and Plant Breeding,
School of Agricultural Sciences,
Karunya Institute of Technology
and Sciences, Coimbatore, Tamil
Nadu, India

Corresponding Author:

Vorem Harsha Kiran

M.Sc. Scholar, Division of
Agronomy, School of Agricultural
Sciences, Karunya Institute of
Technology and Sciences,
Coimbatore, Tamil Nadu, India

Response of foxtail millet (*Setaria italica* L.) to integrated foliar nutrient management

Vorem Harsha Kiran, Augustine R, Praveena Katharine, Lydia Pramitha
and Nivethitha M

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Abstract

The research entitled “Response of foxtail millet (*Setaria italica* L.) to integrated foliar nutrient management” was performed at the South Farm, premises of Karunya Institute of Technology and Sciences, Coimbatore, Tamil Nadu, during Rabi Season 2025. The experiment consisted of 16 treatments with Potassium Nitrate (KNO₃) and Nano Micronutrients [Iron (Fe), Zinc (Zn), Manganese (Mn)] as follows: (T₁) 1% KNO₃ only, (T₂) 1.5% KNO₃ only, (T₃) 2% KNO₃ only, (T₄) 1% KNO₃ + Nano Fe @ 0.5%, (T₅) 1% KNO₃ + Nano Zn @ 0.5%, (T₆) 1% KNO₃ + Nano Mn @ 0.5%, (T₇) 1.5% KNO₃ + Nano Fe @ 0.5%, (T₈) 1.5% KNO₃ + Nano Zn @ 0.5%, (T₉) 1.5% KNO₃ + Nano Mn @ 0.5%, (T₁₀) 2% KNO₃ + Nano Fe @ 0.5%, (T₁₁) 2% KNO₃ + Nano Zn @ 0.5%, (T₁₂) 2% KNO₃ + Nano Mn @ 0.5%, (T₁₃) 1% KNO₃ + (Nano Fe + Nano Zn + Nano Mn @ 0.5%), (T₁₄) 1.5% KNO₃ + (Nano Fe + Nano Zn + Nano Mn @ 0.5%), (T₁₅) 2% KNO₃ + (Nano Fe + Nano Zn + Nano Mn @ 0.5%), (T₁₆) Control (Without foliar spray) and laid out under Randomized Block Design (RBD) replicated thrice. Data were collected on the growth, yield and yield attributing parameters of foxtail millet. The response of (T₁₅) was identified to be the best with growth and yield parameters like Plant height (125.43 cm), number of leaves (27.33), Leaf length (48.03 cm), Leaf width (2.43 cm), Dry matter production (5467.67 kg/ha), Number of panicles (4.00), Panicle length (24.97 cm), Panicle weight (16.66 gm), Grains per panicle (1669.33), Test weight (3.11 gm), Grain yield (2141 kg/ha) and Stover yield (3949.03 kg/ha). The minimum was recorded in treatment (T₁₆) control.

Keywords: Foxtail millet, integrated foliar nutrition, Nano Zinc (Zn), Nano Iron (Fe), Nano (Mn), Potassium Nitrate (KNO₃)

1. Introduction

The global food security situation is threatened by climate change, soil depletion, low nutrition, irregular rainfall, and loss of crop diversity. All major cereals have been documented to have a high contribution to global warming, unlike millets, and thus need to be taken into account in solving global food security issues (Saxena *et al.*, 2018) ^[14]. Millets have been referred to as "miracle crops" owing to all the benefits they offer, including value-added food products, high carbon sequestration due to C4 crops, erosion control in arid lands, and adequate food and nutrition security in smallholder farms in harsh environments. Based on future challenges the United Nations declared 2023 as the International Year of Millets (Kheya *et al.*, 2023) ^[8]. Foxtail millet, one of the world's oldest crops, has remained an underutilized crop in the green revolution and has been kept as a crop of last resort. This crop stands out from other crops because of its strong ability to withstand dry and harsh environments, it is rich in nutritional composition and its long-standing role in supporting food security in several parts of Asia and Africa. In India 12.15 million tonnes of foxtail millet were produced in the year 2025-2026 (USDA 2025) ^[18], and it has played a vital role in rainfed areas in South India. It is rich in nutrients and provides the modern day diet with non-glutinous food that is rich in proteins, essential minerals, fibre, and bioactive ingredients that play important roles in boosting immunity, regulating blood sugars, and antioxidant functions, thereby acting as a powerful functional food that plays a significant role in the prevention of malnutrition and many lifestyle disorders (Jacob *et al.*, 2024) ^[6].

In order to increase the growth and yield of cereal crops despite challenges in rainfed regions,

the integrated foliar nutrition was planned to achieve the higher yields of foxtail millet. Foliar application avoids limitations in the roots, minimizing soil loss and facilitating faster delivery of nutrients, application of KNO_3 , and nano micronutrients of Zn, Fe, and Mn at 30 and 45 DAS to maximize yield in rice (Sreelekshmi and Devi, 2024) ^[17]. Zinc (Zn) plays a role in protein metabolism, antioxidant defense, improvement of root growth, pollen viability, and grain nutritional value through foliar application. Iron (Fe) plays a role in chlorophyll biosynthesis. Manganese (Mn) plays a role in powering photosystem II, nitrogen metabolism, and lignin biosynthesis. Foliar application of Mn maintains enzyme activity, crop health, and stability under varying soil conditions to enhance yields. In view of the above description, the study was conducted to overcome the climate change and global food security factors, with an integrated foliar nutrition approach in rainfed areas, which can tackle global warming.

2. Materials and Methods

2.1 Location of the experiment

The experiment was conducted in South Farm (located between 10°20' and 11°40' North latitude and 76°44' and 77°34' East longitude), Karunya Institute of Technology and Sciences, Coimbatore, Tamil Nadu, during Rabi season of 2025.

2.2 Experimental materials

The variety used was (ATL⁻¹), which attains maturity within 80-85 days under rainfed condition, developed by IIMR, Athiyandal. Sowing was done on 10th September 2026. The net plot size of 4.5 × 3.8 m was prepared with calculated amount of FYM and a basal dosage of NPK 40:20:0 was applied in the form of urea (N), single super phosphate (P₂O₅) as per the calculated amount to each plot. Potassium nitrate (KNO_3), Nano Zn, Nano Fe, Nano Mn were supplied through foliar spray as per treatment requirement. Foliar spray was done on 30th and 45th day. All the intercultural operations were done from sowing to harvest. Harvesting and threshing operations were done manually by separating each plot with the help of sickles and crop was sun-dried before threshing after that stover and grain of each plot were weighed and tagged separately. Five plants were selected randomly for observations and their mean value was recorded as observations of individual growth and yield parameters and are calculated per hectare respectively.

2.3 Treatment details

This experiment was carried out in Randomized Complete Block Design with 16 treatments replicated thrice viz., (T₁) 1% KNO_3 only, (T₂) 1.5% KNO_3 only, (T₃) 2% KNO_3 only, (T₄) 1% KNO_3 + Nano Fe @ 0.5%, (T₅) 1% KNO_3 + Nano Zn @ 0.5%, (T₆) 1% KNO_3 + Nano Mn @ 0.5%, (T₇) 1.5% KNO_3 + Nano Fe @ 0.5%, (T₈) 1.5% KNO_3 + Nano Zn @ 0.5%, (T₉) 1.5% KNO_3 + Nano Mn @ 0.5%, (T₁₀) 2% KNO_3 + Nano Fe @ 0.5%, (T₁₁) 2% KNO_3 + Nano Zn @ 0.5%, (T₁₂) 2% KNO_3 + Nano Mn @ 0.5%, (T₁₃) 1% KNO_3 + (Nano Fe + Nano Zn + Nano Mn @ 0.5%), (T₁₄) 1.5% KNO_3 + (Nano Fe + Nano Zn + Nano Mn @ 0.5%), (T₁₅) 2% KNO_3 + (Nano Fe + Nano Zn + Nano Mn @ 0.5%), (T₁₆) Control (Without foliar spray).

2.4 Statistical Analysis

The data recorded for all parameters were subjected to statistical analysis as per the procedure of Randomized Block Design in OPSTAT. The different effects of treatments showed a significant difference among treatments, critical difference (C.D.) at a 5% level of probability is considered to compare the treatment mean values (Panse and Sukhatme 1985) ^[13].

3. Results and Discussion

3.1 Growth Parameters

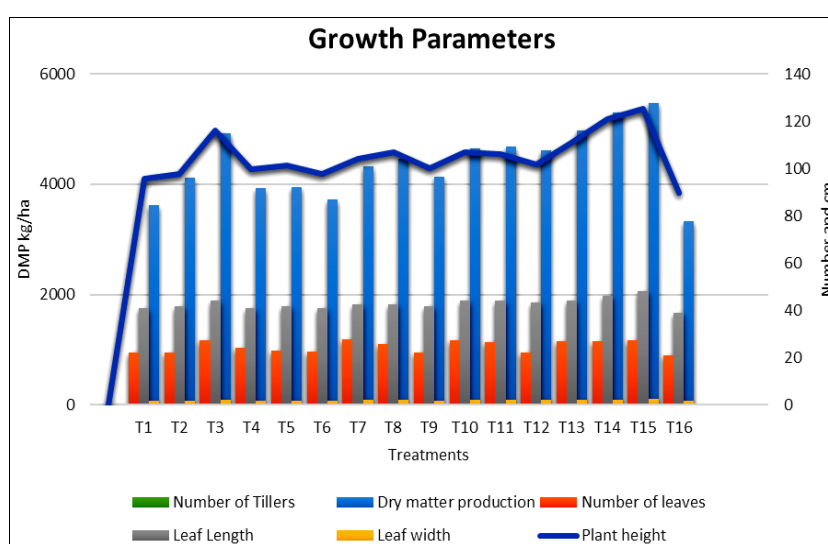
Due to different foliar treatments, there was a significant difference between the growth attributing characters of foxtail millet viz., plant height, no. of leaves per plant, no. of tillers per plant, dry matter production, leaf length and breadth and days to 50% flowering. The maximum plant height of (125.43 cm), leaf length (48.03 cm), leaf breadth (2.43 cm), no. of leaves (27.33), no of tillers (4.67), days to 50% flowering in 46 days and dry matter production (5467.67 kg ha⁻¹) was recorded in treatment (T₁₅) 2% KNO_3 + (Nano Zn + Nano Fe + Nano Mn @ 0.5%) and it was statistically on par with (T₁₄) 1.5% KNO_3 + (Nano Zn + Nano Fe + Nano Mn @ 0.5%) and (T₃) 2% KNO_3 . This enhanced growth can be attributed to the combined effects of both nitrogen and potassium, along with nano-iron, nano-zinc, and nano-manganese, which are vital for the formation of chlorophyll, enzymatic activities, and photosynthetic rates. The nano-formulated micronutrients are well known for their ability to improve nutrient use efficiency by enhancing their uptake and translocation in plants. The accumulation of potassium in vegetative parts of foxtail millet, namely leaves, stems, and panicles, resulted in increased growth. This application of micronutrients in smaller quantities will help in the slow release of nutrients, which will result in increased photosynthesis, development, and growth. The net rate of photosynthesis and the efficiency of leaves increased due to the application of potassium. The increased plant height due to the application of potassium along with basal doses may be due to the elongation of cells. The higher concentration of KNO_3 helps in the quick uptake of nutrients. The increase in leaf area was due to nano micronutrients, which increase the surface area of the leaf. The findings related to growth parameters are similar to those of (Dimkpa *et al.*, 2017) ^[2], (Marzouk *et al.*, 2019) ^[11], (Srinivasa *et al.*, 2020) ^[16], (Li *et al.*, 2022) ^[10], (Yin *et al.*, 2023) ^[20], (Kaviya Shree *et al.*, 2025) ^[9]. Whereas the minimum values were recorded with treatment (T₁₆) Control (Table 1).

3.2 Yield Attributes and Yield

There was a significant difference between the yield attributing characters and yield of foxtail millet viz., No. of panicles, panicle length, panicle weight, grains per panicle, test weight, grain yield, stover yield and harvest index. No. of panicles (4.00), panicle length of (26.97 cm), panicle weight of (16.66 cm), no. of grains per panicle (1,669.33), grain yield of (2141.00 kg/ha), stover yield of (3994.03 kg/ha) all were recorded higher in treatment T₁₅ - (2% KNO_3 + Nano Zn + Nano Fe + Nano Mn @ 0.5%) and it was statistically on par with (T₁₄) 1.5% KNO_3 + (Nano Zn + Nano Fe + Nano Mn @ 0.5%) and (T₃) 2% KNO_3 . The effect of KNO_3 on plants' metabolism with a higher dose was found to enhance the yield attributes. The study on the interaction between nano-Zn and Fe showed that there was a significant increase in the yields and their components. Nutrient uptake leads to increased nutrient accumulation and translocation to developing panicles, which results in increased filling, grain weights, and hence increased yields. Increased test weights this could be attributed to the effect of nano micronutrients on foxtail millet. Nutrient uptake by the plants enhances cell division, physiological activities, and nutrient supply for increased crop yield. Similar findings were reported by (Waraich *et al.*, 2011) ^[19], (Drostkar *et al.* 2016) ^[3], (El-Metwally *et al.*, 2018) ^[4], Gomaa *et al.* (2018b) ^[5], (Mudalagiriappa *et al.*, 2020) ^[12], (Kaviya Shree *et al.*, 2025) ^[9], (Jawahar *et al.*, 2025) ^[7], (Singh *et al.*, 2025) ^[15]. Whereas the minimum was recorded with treatment (T₁₆) Control (Table 2).

Table 1: Influence of integrated foliar nutrition on growth parameters of foxtail millet

Treatment No	Plant height (cm)	Number of Leaves	Leaf Length (cm)	Leaf width (cm)	Dry matter production (kg/ha)	Number of Tillers
T ₁	95.67	22.33	40.90	1.70	3620	3.67
T ₂	97.57	22.33	41.53	1.87	4105.33	3.67
T ₃	116.17	27.33	44.30	2.20	4910.77	4.67
T ₄	99.63	24.00	40.93	1.67	3920	4
T ₅	101.13	23.00	41.80	1.70	3950.33	4
T ₆	97.57	22.67	41.00	1.70	3712	3.67
T ₇	104.13	27.67	42.47	1.97	4325.77	4.33
T ₈	106.87	25.67	42.47	2.00	4459	4.67
T ₉	100.17	22.33	41.87	1.93	4133.33	3.67
T ₁₀	106.87	27.33	44.00	2.07	4652.67	4.33
T ₁₁	106	26.67	44.13	2.07	4678.47	4.33
T ₁₂	101.83	22.33	43.13	2.03	4603.33	4
T ₁₃	110.67	27.00	44.23	2.27	4962.2	4.33
T ₁₄	120.67	27.00	46.03	2.30	5298.33	4.67
T ₁₅	125.43	27.33	48.03	2.43	5467.67	4.67
T ₁₆	89.87	21.00	39.07	1.63	3321.4	3.33
CD	9.07	2.33	3.604	0.17	585.41	0.42
SE (d)	4.44	1.14	1.756	0.08	286.65	0.205

**Fig 1:** Graph illustrating Influence of integrated foliar nutrition on growth parameters of foxtail millet**Table 2:** Influence of integrated foliar nutrition on yield and yield attributes of foxtail millet

Treatment no	No. of panicles	Panicle length (cm)	Panicle weight (gm)	Grains per panicle	Test weight (gm)	Grain yield (kg/ha)	Stover yield (kg/ha)
T ₁	3	15.8	10.72	1,223.00	2.69	1519.67	2917.23
T ₂	3.33	16.23	11.18	1,305.00	2.72	1646.33	3172.37
T ₃	4	21.89	15.19	1,473.67	3.01	1942.67	3222.93
T ₄	3	15.17	10.14	1,263.00	2.67	1532	3005.97
T ₅	3.33	16.27	11.19	1,272.00	2.71	1566.67	2914.2
T ₆	3	15.3	10.26	1,256.00	2.71	1530	2941.33
T ₇	3.67	16.4	11.38	1,378.33	2.77	1674	3150.6
T ₈	3.67	17.13	12.57	1,399.00	2.79	1694	3249.37
T ₉	3.67	15.57	10.66	1,364.33	2.73	1661	3163.77
T ₁₀	4	19.13	13.69	1,432.00	2.83	1712.67	3360.23
T ₁₁	4	19.5	13.96	1,424.00	2.84	1746	3475.97
T ₁₂	3.33	18.23	12.96	1,416.00	2.75	1702	3286.93
T ₁₃	3.67	21.33	15.01	1,467.33	2.91	1895.33	3931.53
T ₁₄	4	23.9	16.51	1,595.00	3.09	2057	3990.87
T ₁₅	4	24.97	16.66	1,669.33	3.11	2141	3934.03
T ₁₆	2.67	14.8	8.76	1,101.67	2.2	1202	1996.87
CD	0.453	3.12	1.1	136.45	0.2	262.72	2917.23
SE (d)	0.222	1.53	0.53	66.8	0.09	128.64	3172.37

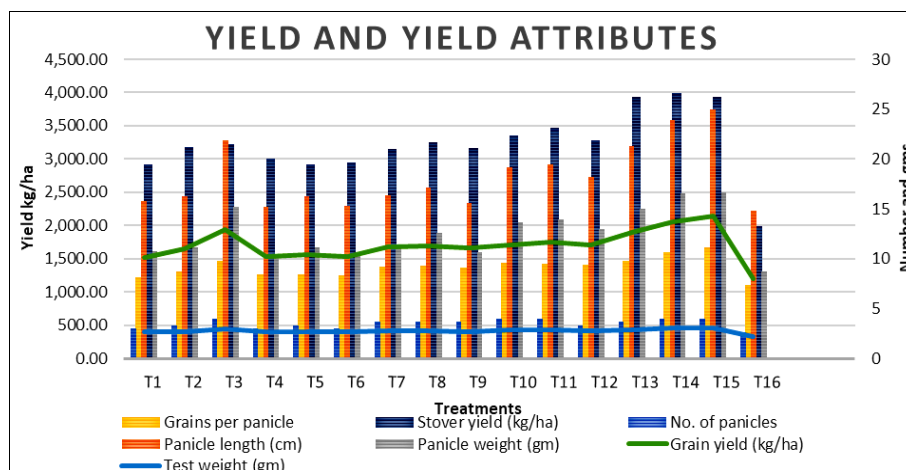


Fig 2: Graph illustrating Influence of integrated foliar nutrition on Yield parameters of foxtail millet

4. Conclusion

The present study reveals that the influence of integrated foliar nutrient management practices of both macro and micro nutrients as an integral approach for enhancing growth and yield of the crop in rainfed conditions. Based on the results obtained from the present study, it is to be concluded that the application of 2% KNO₃ + (Nano Zn + Nano Fe + Nano Mn @ 0.5%) can increase the growth attributes throughout the cropping period and managed to achieve higher yield of the crop under rainfed condition, on the other hand application of 2%KNO₃ also influenced the crop and led to increased growth and yield of foxtail millet.

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